Granular Activated Carbon (GAC) Biofilter in Water and Wastewater Treatment

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CERTIFICATE

I certify that this thesis has not already been submitted for any degree and is not being submitted as part of candidature for any other degree.

I also certify that the thesis has been written by me and that any help that I have received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

Signature of Candidate

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Nomenclature

A = the specific surface area of the media

ATP = adenosine triphosphate

BOD_5 = biochemical oxygen demand

b_{tot} = Total biofilm loss efficient (s^{-1})

$btot$ = the total biofilm loss coefficient

C = the liquid phase concentration.

C_0 = initial TOC concentration of synthetic wastewater (mg/L)

C_e = the equilibrium organic concentration (mg/L)

COD = chemical oxygen demand

CFU = Number of Colony forming units

D_{ax} = the axial dispersion coefficient

DBPs =disinfection by products

D_f = the molecular diffusivity within biofilm

D_L = axial dispersion coefficient

DNA = deoxyribonucleic acid

DO = Dissolved oxygen

DOC = dissolved organic matter

D_s = diffusion coefficient (, m^2/s)

D' = the dispersion coefficient (m^2/s)

EBCT = empty bed contact time

EPS = extracellular polysaccharides

GAC = granular activated carbon

H = Henry law's constant

HAAs = haloacetic acids

HLR = Hydraulic loading rate

J_f = the flux of substrate into the biofilm ($mg/m^2/s$)

k = the maximum rate of substrate utilization (mg/mg/s)

K = reaction constant

K_d = Decay coefficient (s^{-1})

K_f = film mass transfer coefficient (m/s)

K_S = Solid phase mass transfer

Ks = the Monod half-velocity coefficient (mg/L)

K_{max} = Maximum rate of substrate utilization

k_P = the particle phase mass transfer coefficient

L = reaction constant

LDFA = Linear driving force approximation

L_f = the biofilm thickness

L_{f0} = Biofilm thickness (m)

M = the weight of used GAC (g)

MW = Molecular weight (Dalton)

NDIR = Non-dispersive infrared gas reactor

N = The adsorbate uptake rate per pellet

P_n = the number of characteristic packing spheres.

NOM = natural organic matter

q = the adsorbed-phase concentration

q_m = saturation amount of organic adsorbed (mg/g)

q_S = the value of q at pellet surface

RNA	=	ribonucleic acid
S	=	substrate concentration (mg/L)
TOC	=	Total organic carbon (mg/L)
TC	=	Total carbon (mg/L)
TIC	=	Total inorganic carbon (mg/L)
THMs	=	trihalomethanes
u	=	the interstitial velocity
V	=	the volume of solution (mL)
VSS	=	volatized suspended solids
x	=	the distance along the biofilter length (m)
X_f	=	the cell density of biofilm
X_{susp}	=	the suspended cell concentration (mg/L)
Y	=	Yield coefficient (mg/mg)
β	=	the filtration efficiency
σ	=	the biofilm shear loss coefficient (s^{-1})
ε_b	=	the bed porosity
μ	=	specific growth rate
μ_m	=	the maximum growth rate
θ	=	the empty bed contact time
v	=	fluid velocity (m/s)
ψ	=	organic concentration spreading parameter

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Abstract

Biofilters can effectively remove organic matters from water and wastewater. Basically, the success of operation of a biofilter depends mainly on the activities of the microbial community in the filter. Organic substances are adsorbed onto filter media and then biodegraded by those microbes.

The experimental investigation of the granular activated carbon (GAC) adsorption indicated that GAC exhibited a high organic removal rate by adsorption in both the batch and column experiments. The GAC adsorption equilibrium with synthetic wastewater fitted better with association theory (Talu) than with Freundlich and Sips models. Adsorption kinetics and fixed bed of GAC with organic matter was well described and predicted by the Linear Driving Force Approximation (LDFA) model. Long term GAC biofiltration was mathematically described using a simple model which incorporated both adsorption and biodegradation. The model was mainly successful in describing the biological phase.

Biomass accumulation onto GAC was evaluated in terms of dry mass and number of viable cells both in the batch and column experiments. The attachment of micro-organisms onto the GAC surface depended on the hydraulic loading rate and influent concentration. The amount of dry mass retained on GAC in the column was double than that in batch test in the steady state with 44mg/g GAC and 85mg/g GAC respectively. More viable cells were enumerated from GAC in the experiments with synthetic wastewater than with river water. The prominent bacteria isolated from GAC biofilter for synthetic wastewater and river water included: *Pseudomonas Aeruginos, Pseudomonas Alcaligenes, Brevibacterium Otitidis, Enterobacter Cloacae, Enterobacter Aerogenes, Staphylococcus Epidermidis and Kocuria Rosea*.

The long term performance of the GAC biofilter with synthetic wastewater which has similar characteristics to biologically treated sewage effluent and river water was experimentally evaluated. The result showed that the GAC biofilter could maintain high

organic removal efficiency after a long filtration time without any regeneration of activated carbon. Even after 42 days of continuous run, the biofilter of very short depth of 15cm GAC bed depth maintained a consistent organic removal efficiency of 40-50% with synthetic wastewater and 55% with river water. GAC biofilter also removed 60-98% of total coliforms from synthetic wastewater and river water. Especially, no fecal coliforms were detected in effluent from the GAC biofilter for river water.

The daily backwash adopted to avoid the physical clogging of the biofilter did not have significant effect on the performance of the filter. The change of filter bed depths, filtration rates and influent concentrations affected the performance of the GAC biofilter. Total organic carbon (TOC) removal efficiency in the higher filter bed was significantly better than that with shallow bed depth (60% TOC removal with a 30cm- bed depth while only 30% with a 5 cm - bed depth). As expected, the efficiency in organic removal decreased with an increase in the filtration rate. The difference was more significant in the lower bed. TOC removal efficiency of the biofilter was also affected by the concentration of influent. It increased with the increase in the concentration of influent, but the TOC removal pattern with time was almost the same. Further, the increase of organic removal rate was not proportional to the rise of influent concentration.

A study with different filter media showed that GAC as filter media was superior to plastic bead, anthracite and sponge in terms of organic removal. In addition, GAC was combined with sponge or polypropylene as medium to enhance the effectiveness of biofilter in removing organic matter. The use of sponge and floating media can eliminate further 10-20% of TOC from the effluent of GAC biofilter with less effort in installation, operation and maintenance.

In summary, GAC biofilter can be used as an economical treatment system in removing organic matters and pathogens from biologically treated wastewater and surface water. The merits of GAC biofilter are the consistent of TOC removal efficiency, long life cycle, and simplicity in operation. The combined system of GAC - sponge filter media biofilter can be an effective and a good practical solution for improving the organic removal from water and wastewater.